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WALTERSBURG SANDSTONE OIL POOLS OF LOWER WABASH AREA, ILLINOIS AND INDIANA

BY

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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WALTERSBURG SANDSTONE OIL POOLS OF LOWER WABASH AREA, ILLINOIS AND INDIANA[1]

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Urbana, Illinois

ABSTRACT

Oil in the Waltersburg sandstone of the upper part of the Upper Mississippian Chester series in the Eastern Interior basin occurs in diverse structural situations, not only on and near the crests of anticlines and the upthrown sides of faults, but also on unfaulted regional monoclines, low on the flanks of anticlines, and on the downthrown sides of faults. Waltersburg oil is trapped in a remarkable series of bar-like sandstone bodies, some entirely surrounded by shale. Though several processes may have joined in forming these bar-like features, petrographic and stratigraphic studies point to the deposition of their well sorted sands in a near-shore or shore-line environment by wave and current action. The near-shore facies extends beyond the area of commercial Waltersburg oil pools. Several hundred wells have been drilled to deeper horizons through Waltersburg sand bodies west of the productive region without encountering oil in the formation. As the productive Waltersburg region is almost co-extensive with the post-Pennsylvanian normal fault system of the southeast flank of the basin, the migration of oil along fault planes from lower sources may be in part responsible for accumulation in the Waltersburg lenses, though some occurrences can not be explained in this way. Two recent major Waltersburg discoveries have resulted from facies analysis through the projection of imperfectly known sandstone lenses into structural situations in which the lenses could act as oil traps.

INTRODUCTION

At least 70 million barrels of oil recoverable by normal primary methods has been discovered in the Waltersburg sandstone (Upper Mississippian, Chester series) of the Eastern Interior basin up to January, 1950. Over half is from pools in an area of about 550 square miles along the lower reaches of the Wabash River (Figs. 1 and 2) and most of the rest comes from pools within 18 miles northeast, east, and southeast. The area mapped in detail borders the southeast side of the deepest part of the Eastern Interior basin and is a few miles north of the Rough Creek-Shawneetown fault zone. It offers examples which are typical of the Waltersburg pools of the entire basin. The area is partly in Illinois, partly in Indiana, and touches the Kentucky boundary.

The maps were compiled at different times from 1948 to 1951.

[1] This paper includes material read before the Association in the Research Committee Symposium on Control of Oil and Gas Accumulation by Sedimentary Facies at the St. Louis meeting, March 14, 1949. Figs. 4 and 5, on a scale of 1 inch = 1 mile, are available at cost of reproduction from the Illinois State Geological Survey, Urbana.

[2] Geologist, Illinois Geological Survey.

This study was aided by the officers and members of the Illinois Geological Society and the Indiana-Kentucky Geological Society. C. A. Bays, consulting geologist, Clarence Brehm, consulting geologist, E. J. Combs of the Sun Oil Company, R. C. Cooper of the Sinclair Oil and Gas Co., Joseph Neely of the Magnolia Petroleum Company, and Lloyd Harris of the Carter Oil Company were particularly helpful in supplying information, logs, and cores. Elwood Atherton, A. H. Bell, and L. E. Workman of the Illinois State Geological Survey gave helpful advice, and Raymond Siever examined thin sections. Karl Goodall, Robert Murphy, Dan Melrose, John Mortimer, and William McKain, students at the University of Illinois and part-time workers for the Illinois Geological Survey, assisted in much of the checking of well logs and plotting.

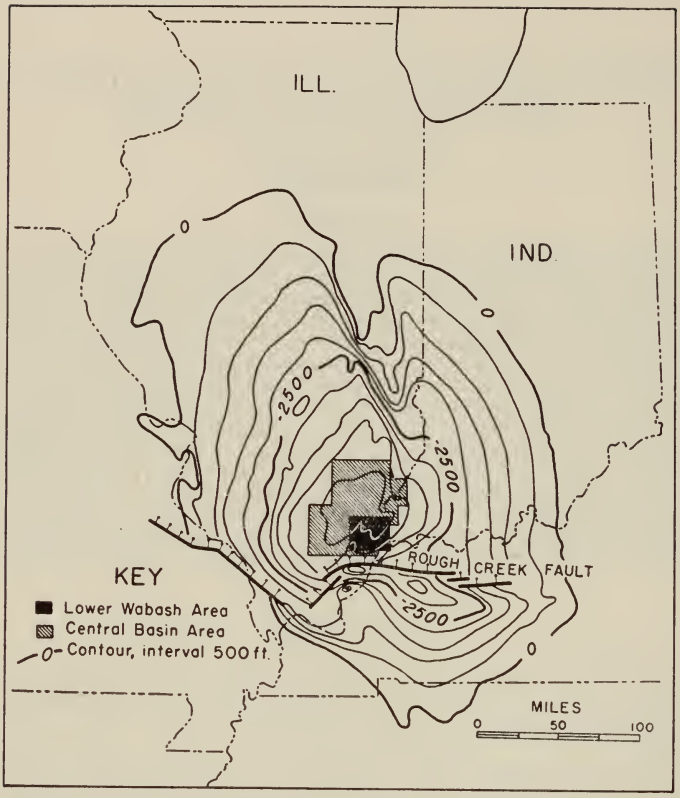


FIG. 1.—Structure of Eastern Interior basin on base of New Albany shale (top of Devonian-Silurian carbonate sequence), showing position of lower Wabash area (Figs. 2, 4, 5) and central basin area (Fig. 13).

CHESTER SERIES

Although within the lower Wabash area small amounts of oil come from Pennsylvanian sandstones and from limestones of the Lower Mississippian, 90 per cent of the oil comes from sandstones of the Upper Mississippian, Chester series. Chester sandstones have accounted for only a little more than half of the oil produced from the entire Eastern Interior basin. Thus, they are more important here than in some other parts of the basin.

The Chester series consists of a rather complex sequence of beds of shale, sandstone, and limestone 1,000–1,300 feet thick in the lower Wabash area (Fig. 3). At any point the Chester shales aggregate approximately 600–800 feet and the sandstones and limestones 200–250 feet each. The Chester is commonly described as a series of alternating limestone and sandstone formations, but it is more accurately a mass of shale in which there are several fairly extensive continuous limestones, some less extensive limestone lentils, and a considerable number of sandstone lenses of varying sizes and shapes.

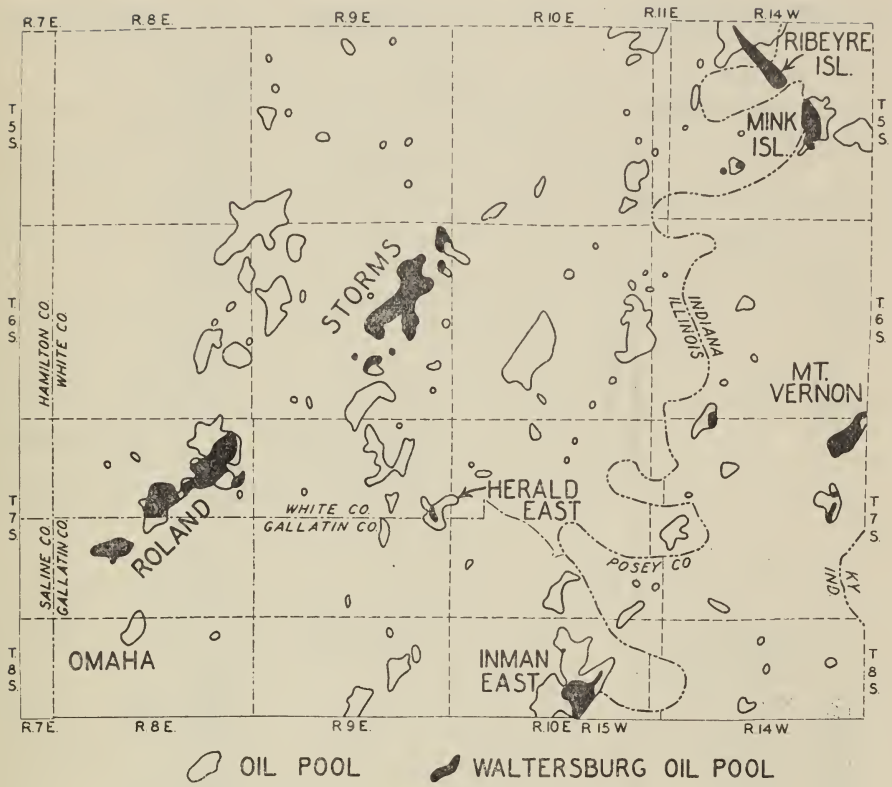


FIG. 2.—Oil fields of lower Wabash area.

Examples of complete or partial control of oil accumulation by changes in sedimentary facies can be found in every producing Chester sandstone. In the lower Wabash area such sandstones occur at fifteen or sixteen positions within the Chester series (Fig. 3). Other sandy zones in this vicinity are shaly or calcareous, but are better developed and contain oil in other parts of the basin. Here the Waltersburg sandstone, though overlain by four beds which produce oil, is the highest Chester producing zone of major importance. It exhibits many very clear-cut facies traps.

Facies changes in the Waltersburg formation are of classic simplicity and clarity. Variations in porosity due to calcareous and ferruginous cement which complicate the sandstone-shale relations in some other Chester beds such as the "Basin Aux Vases" are at a minimum here. Erosion has obscured the pattern of deposition of such Chester sandstones as the upper Paint Creek, lower Cypress, and lower Bethel, but not of the Waltersburg. Because it is high in the section drilled for oil, numerous wells penetrate the Waltersburg in both its productive and non-productive phases. Its identity and correlation present few problems.

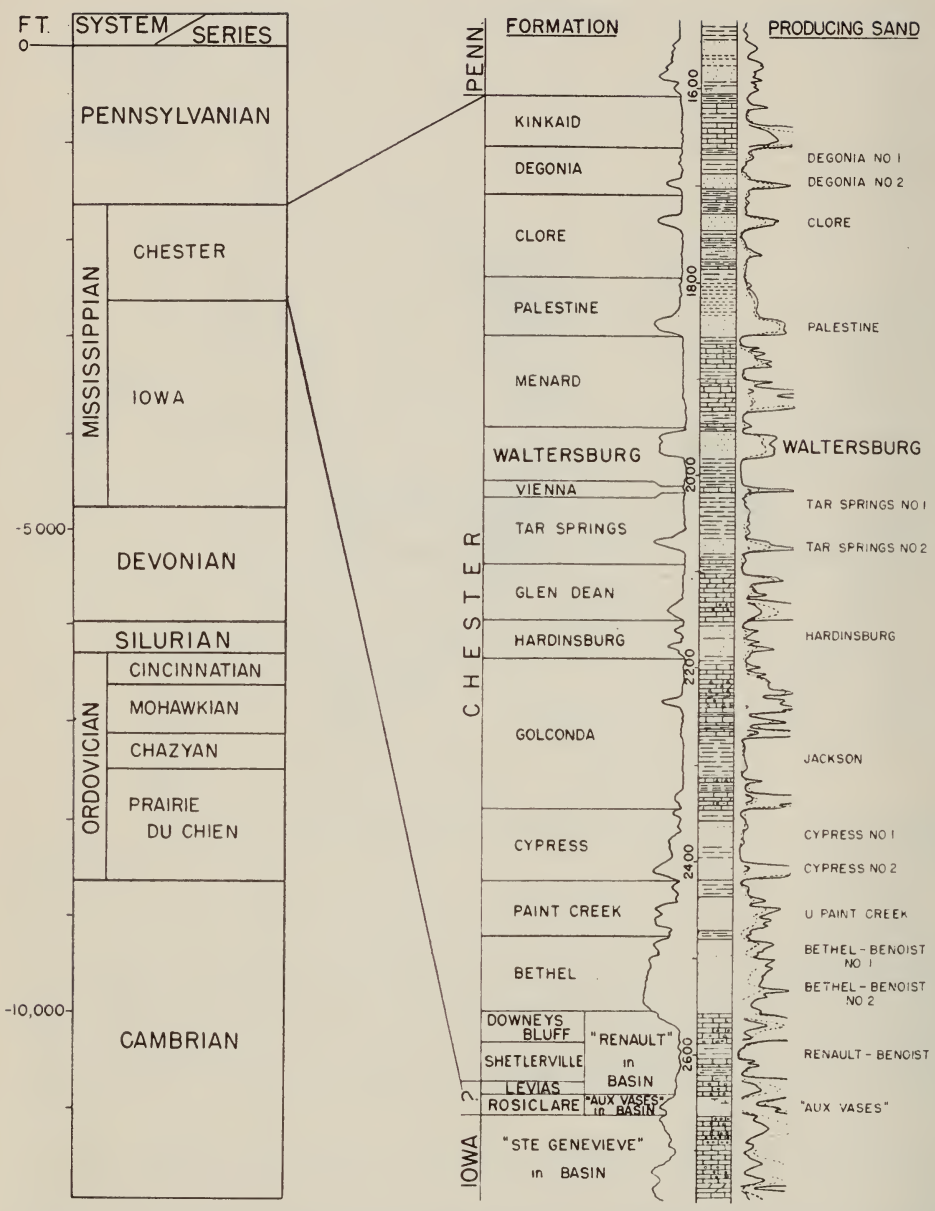


FIG. 3.—Stratigraphic section for lower Wabash area. "Pay sands" listed at right are all productive in the area, though not in the well represented, Cherry and Kidd's Kerwin No. 12, Sec. 11, T. 8 S., R. 10 E., Inman East field, Gallatin County, Illinois. Relation of lower Chester units, locally recognized, to those in other parts of the basin is shown in D. H. Swann and Elwood Atherton, "Subsurface Correlations of Lower Chester Strata of the Eastern Interior Basin," *Jour. Geol.*, Vol. 56, No. 4 (July, 1948), pp. 269–87; *Illinois Geol. Survey Rept. Inv. 135.*

For these reasons the Waltersburg is perhaps ideal among the Chester sandstones for demonstrating stratigraphic traps.

The Menard formation of interbedded limestone and shale immediately overlying the Waltersburg (Figs. 3 and 12) is readily recognized and traced from the outcrop belts.[3] It includes a number of thin but extremely persistent limestone beds, some of which can be recognized throughout the entire basin. The top of the middle or massive member of the Menard, which is indicated on the log sections (Fig. 12), is used as the contour surface on the structure map (Fig. 4), although other horizons in the Menard can be equally well contoured. The lowest limestone bed in the Menard, commonly called the "Little Menard," is frequently used. Below the "Little Menard" is a shale 50–70 feet thick in this area in which are imbedded the Waltersburg sandstone lenses. At the base of the Waltersburg shale-and-sandstone unit there is a thin but persistent limestone, the Vienna, in nearly all wells in the lower Wabash area which serves to demark the Waltersburg from the next lower and rather complex sandstone-and-shale formation, the Tar Springs.

STRUCTURE

The structure of the top of the middle or massive member of the Menard formation in the lower Wabash area is shown in Figure 4. The regional dip is toward the center of the basin which is beyond the northwest corner of the map. Each fault zone is resolved into separate straight *en échelon* components although, with three or four exceptions, single curving surfaces would be in accord equally well with available data. The faults are all normal and their dips, where known, are between 60° and 70°. Faults which have been carefully mapped through pool areas are not single breaks but zones about 400 feet wide with displacement along several subparallel surfaces. Faulting is post-Pennsylvanian and, so far as is known, the amount of throw does not vary with depth.

The fault zones enclose two anticlinal grabens, the Wabash River structure which extends northeastward for more than 10 miles beyond the map area, and an unnamed one near the southeast corner of the map. Production at the crest of the Omaha dome near the southwest corner of the map has been described.[4]

Correlation between structure and oil production in this region is evident. Most oil fields in the area, including certain Waltersburg pools such as Inman East on the south border of the map, show strong structural control. By contrast many pools, both in the Waltersburg and in other formations, have no structural

[3] Elwood Atherton, "Some Chester Outcrop and Subsurface Sections in Southeastern Illinois," *Trans. Illinois Acad. Sci.*, Vol. 40 (1948), pp. 122–30; *Illinois Geol. Survey Circ. 144.*

F. E. Tippie, "Subsurface Stratigraphic Sections near Type Chester Localities in Southwestern Illinois," *Trans. Illinois Acad. Sci.*, Vol. 35 (1943), pp. 141–44; *Illinois Geol. Survey Circ. 102.*

L. E. Workman, "Subsurface Geology of the Chester Series in Illinois," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 2 (February, 1940), pp. 209–44; *Illinois Geol. Survey Rept. Inv. 61.*

[4] R. M. English and R. M. Grogan, "Omaha Pool and Mica-Peridotite Intrusives, Gallatin County, Illinois," *Structure of Typical American Oil Fields*, Vol. III, Amer. Assoc. Petrol. Geol. (1948), pp. 189–212; *Illinois Geol. Survey Rept. Inv. 130.*

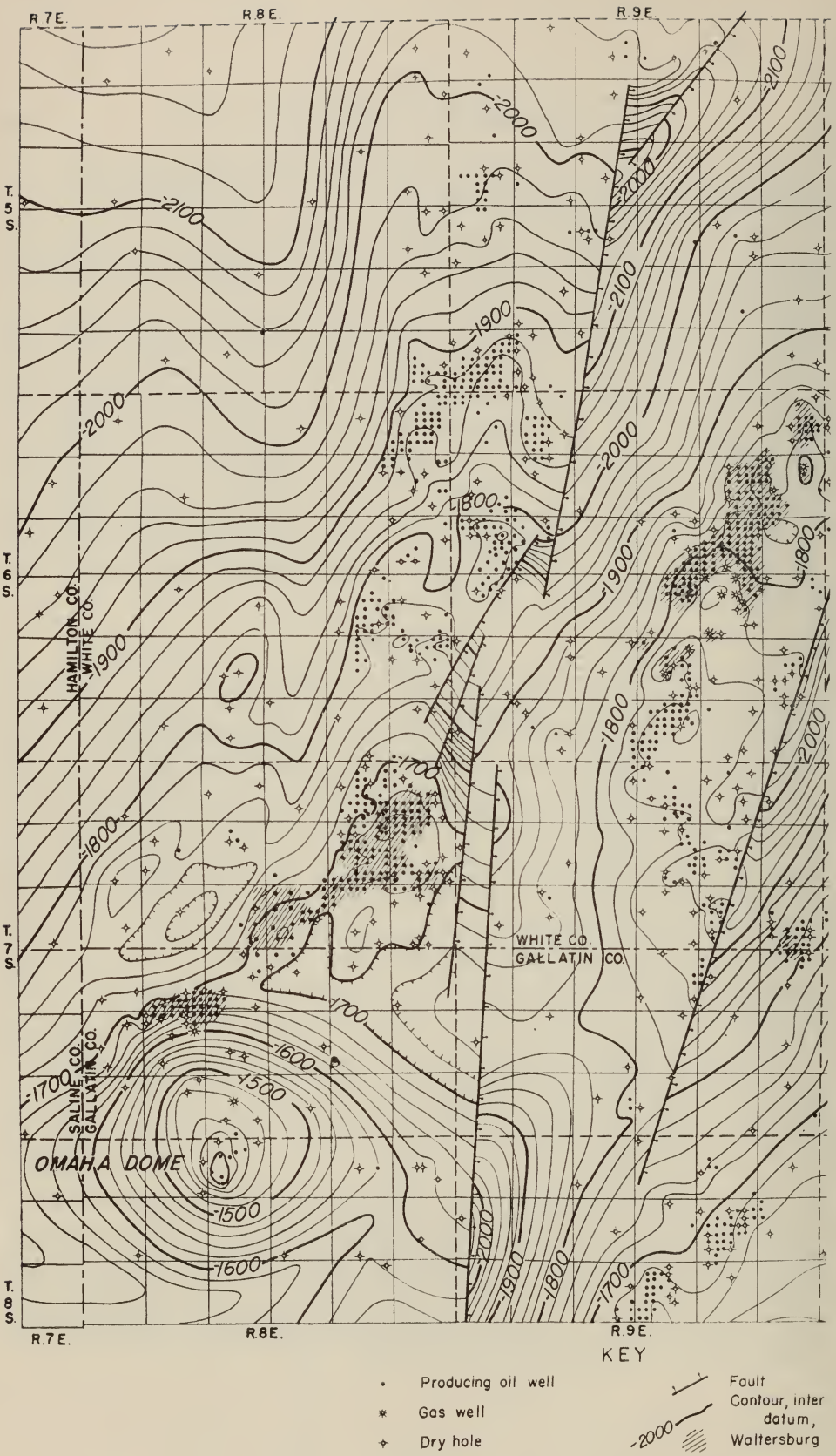
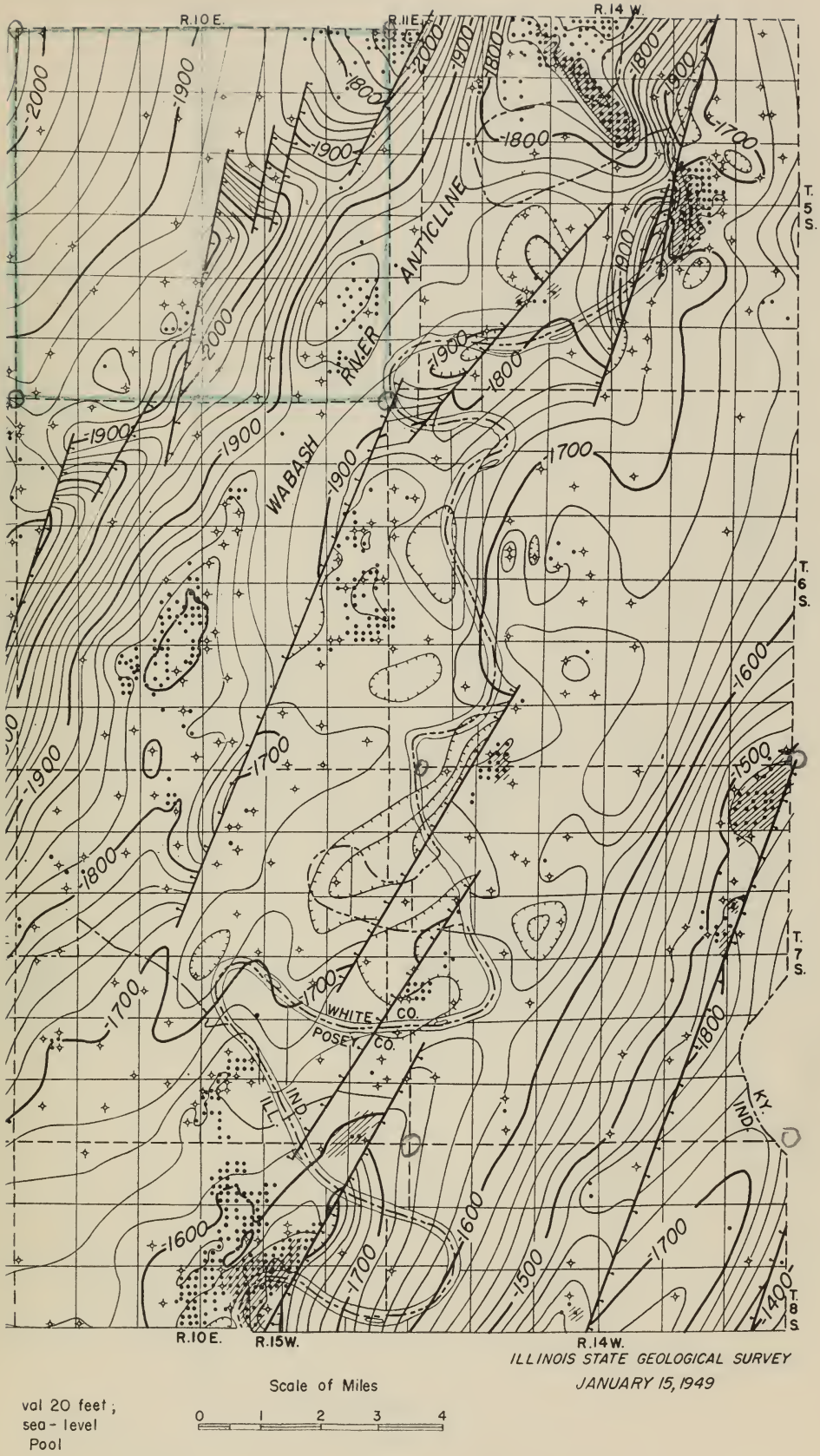


FIG. 4.—Structure of lower Wabash area on



top of middle "massive" Menard limestone.

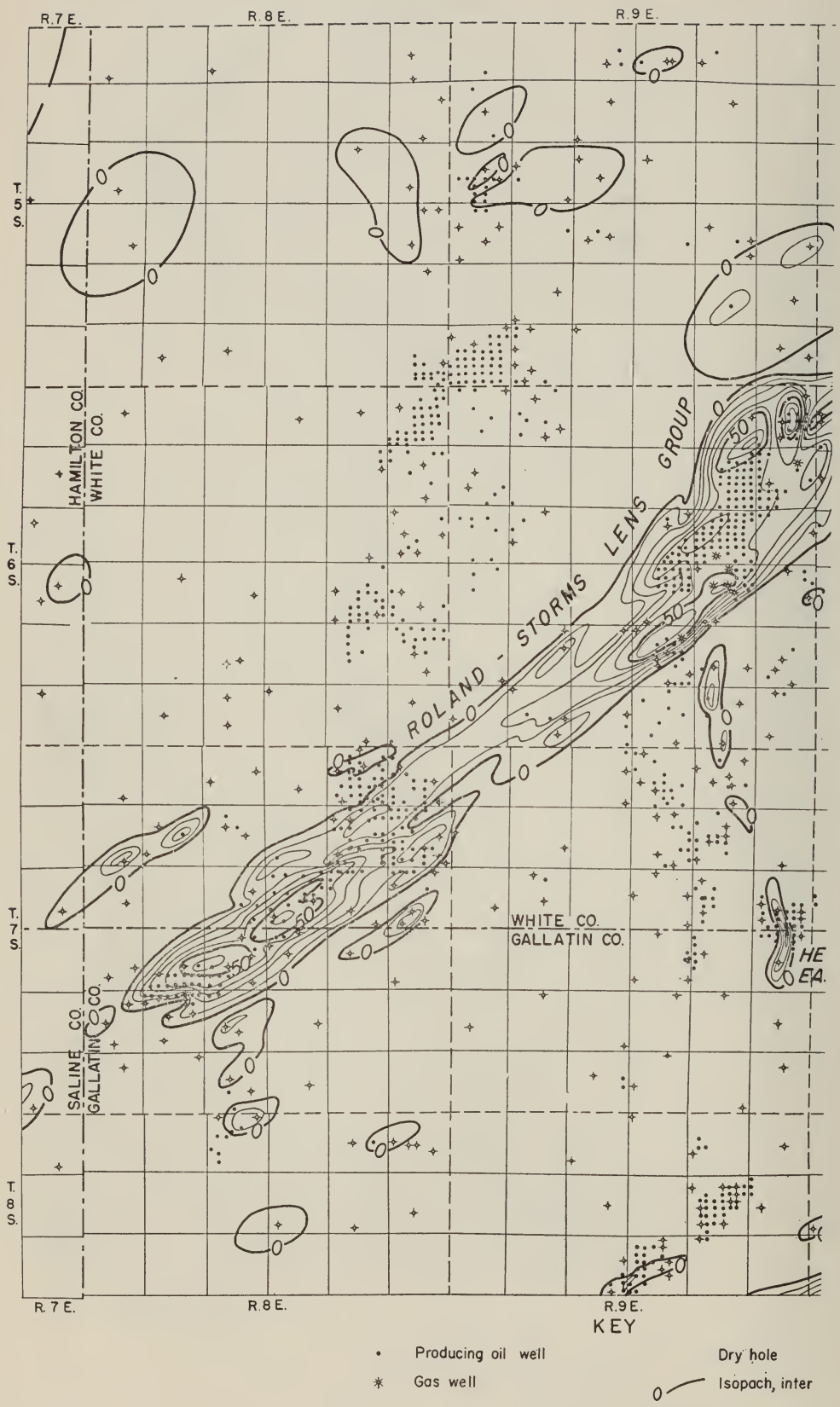
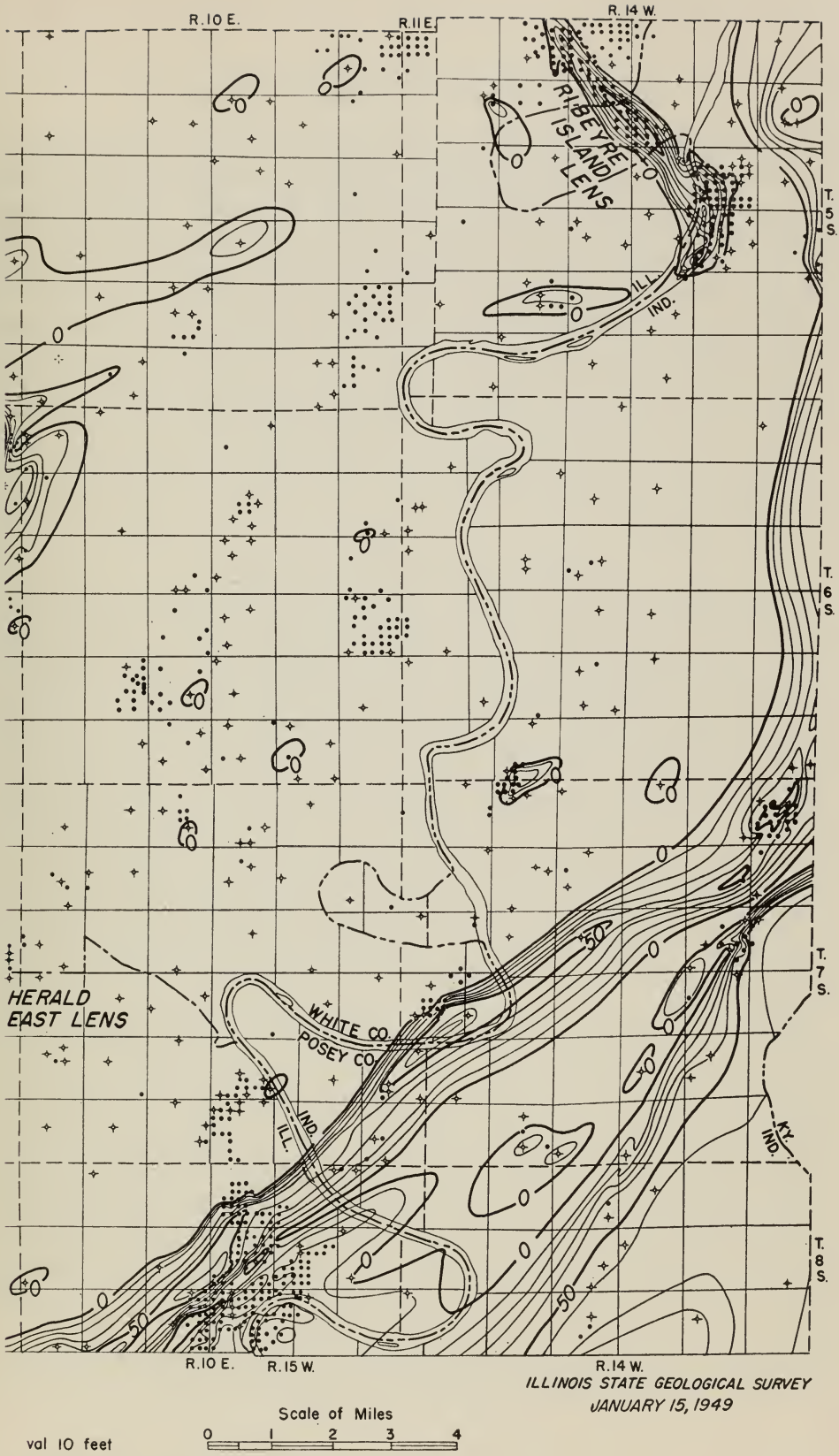


FIG. 5.—Thickness of permeable sandstone in



Waltersburg formation of lower Wabash area.

closure. The Waltersburg pool forming the southwest extension of Roland field, which lies low on the north flank of the Omaha dome near the southwest corner of the map, is a striking example. The small Herald East field, a short distance south of the center of the map, is another. The Storms pool at the center of the map has some closure on the Menard which is not present in maps drawn on the Vienna or other markers below the Waltersburg. This is demonstrated at least partially by a cross section (*BB'*, Fig. 12) just south of the edge of the Storms pool showing divergence of beds above and below the Waltersburg. In this north-south section the Vienna maintains the normal northward component of the regional northwest dip. This component is reversed in the Menard and higher formations, which arch up northward over a Waltersburg sandstone lens. The reversal probably is due to differential compaction of the Waltersburg shale and sandstone and is responsible for part though not all of the closure on Storms pool shown in Figure 4.

WALTERSBURG LITHOLOGIC CHARACTER

A well drilled at random in the lower Wabash area generally encounters only shale in the interval between the Menard and Vienna limestones. The shale is rather monotonously gray, varying only from a light medium gray to a dark medium gray, moderately fissile, and somewhat carbonaceous. Much of it is silty and a few beds are argillaceous siltstone. In the upper part of the interval carbonized leaf impressions, such as the *Cordaites* fragment shown in Figure 6, are not uncommon, and thin (one- to two-inch) coal beds are known in some localities. Apparently beds with marine fossils are present in some places in the lower part of the shale, for ostracodes, fenestellid Bryozoa, small crinoidal ossicles, and fragments of brachiopod shells have been noted in cuttings, seemingly in place. However, there is some possibility of contamination by caving, and cores with marine fossils have not been recovered. When marine fossils have been noted in outcrops, the beds have been included in the Vienna formation. Smooth green to greenish-gray shale occurs near the base of the shale unit interbedded with the typical gray rock.

The coarsest rock encountered in most wells is argillaceous siltstone or argillaceous extra-fine sandstone with prominent shale laminae. Figures 7 and 8 show a thin section of the coarsest rock in a diamond-drill core through the entire Waltersburg interval several miles west of the lower Wabash area. Sorting is fair within individual laminae of the coarser sizes, but it is obvious that a sieve analysis of the entire rock would be interpreted as showing poor sorting. The grain size is about 0.06–0.10 mm., silt and extra-fine sand, in the coarse laminae and 0.01–0.03 mm. in the fine. Quartz, almost to the exclusion of all other constituents, forms the larger grains both in the coarse and fine bands. Two or three per cent of the grains are chert; there are a few shreds of muscovite mica, but no feldspar has been observed. Clay minerals, largely concentrated in the fine-grained laminae, make up about 15 per cent of the rock. Secondary quartz and calcite cement the grains tightly and there is no void space visible.

In contrast to the shale sections usually encountered, in some wells the Waltersburg interval includes sandstone. Figure 9 illustrates this phase from a 15-foot sandstone core from a producing Waltersburg well in a Kentucky pool just south of the mapped area. This well is only 660 feet from the dry hole which at the same level encountered the silty shale pictured in Figure 6.

The cleanest sandstone phase of the formation has been called the "Island Waltersburg" since its discovery in 1938 beneath Ribeyre Island (Figs. 2, 4, and 5), a cut-off part of Indiana west of the present course of the Wabash River in T. 5 S., R. 14 W. The thin-section field shown in Figures 10 and 11 illustrates the features of this phase although the specimen pictured is from the Roland area rather than Ribeyre Island. The rock is a well sorted permeable quartzose sandstone largely composed of what were originally subrounded to rounded grains of normal igneous quartz, with about 10 per cent strained quartz of metamorphic origin and 3 per cent chert grains. Significantly, feldspar and mica are absent. The modal diameter is about 0.16–0.18 mm., in the fine sand range, and the largest observed dimension is only 0.38 mm., medium sand. "Dust rings" marking the original rounded outline of many grains can be observed under high magnification, but the shape of nearly all grains is somewhat modified by the addition of secondary quartz. This secondary quartz is the common cementing material. In parts of the thin section not shown in the photographs there are patches of optically continuous carbonate, each surrounding several sand grains. The carbonate, however, forms less than 1 per cent of the rock. Small pockets of clay minerals are found between some grains, but by comparison with most Chester and Pennsylvanian sandstones of the area, the rock is exceptionally clean and free from clay.

The porosity is 19½ per cent by core analysis and the voids are large, many exceeding the largest grain size. The sample analyzed from this particular foot of sandstone had 1,569 millidarcys permeability. In a hand specimen or core biscuit the "Island Waltersburg" generally has no obvious bedding, but thin sections under very low magnification show vague laminae with varying amounts of porosity and slight changes in grain size. In the typical "Island" phase there is no shale interbedded with the sandstone, and uninterrupted sand sections 50–60 feet thick are found.

A third phase of the Waltersburg can be recognized. Along the eastern edge of the map area (Figs. 2, 4, and 5) and north and east of this area many wells encounter Waltersburg sections in which there is an alternation of shale and of sandstone which is more carbonaceous than in the "Island" phase, and in which partings of shale are rather common. Such examples of shaly sandstone are rare in the central and western parts of the lower Wabash area, where the contrast between the shale facies and the clean sandstone facies is remarkably sharp.

CROSS SECTIONS

Productive Waltersburg sandstone lenses of the typical "Island" phase commonly have flat bedding-plane bottoms (Fig. 12, section *BB′*); that is, the

base of each sandstone lens is essentially parallel with the underlying Vienna limestone, and rests in apparent conformity on the marine shales which lie just above the Vienna. The Waltersburg differs in this respect from several other Chester sandstones such as the Hardinsburg, "Jackson," and Cypress, whose lenses commonly lie in well marked "channels" cut unconformably into the subjacent formations.

The upper surfaces of some Waltersburg sandstone bodies are convex if structural deformation is disregarded; the shale above a lens and beneath the Menard limestone is somewhat thinner over the thicker parts of the lens, though not enough to keep the higher formations from being upwarped over the sand body. A rule of thumb which appears valid for the Waltersburg as well as many other Chester sandstones is that 10 feet of sand replaces about 5 feet of shale. Thus, if there is 30 feet more sand in one well than in another nearby, the "Little Menard" and Vienna will be about 15 feet farther apart in the well with the thicker sand. In general there appears to be compensation in higher beds for exceptionally thick sandstones, several examples of which have been shown previously,[5] including some over Waltersburg lenses.[6]

A section across a lens in Herald East field with known minimum length of nearly a mile, maximum thickness of 35 feet, and width of no more than 1,000 feet is shown in Figure 12, section *CC'*. Well 13, which was completed in a lower sand could not make a commercial well in the Waltersburg though it is only 50 feet distant from well 14, a Waltersburg oil well. There are instances of Waltersburg sandstone bodies 50 feet thick in wells spaced only 660 feet laterally from locations at which there is no sandstone.

[5] D. H. Swann and Elwood Atherton, "Subsurface Correlations of Lower Chester Strata of the Eastern Interior Basin," *Jour. Geol.*, Vol. 56, No. 4 (July 1948), pp. 269–87, Figs. 3–6; *Illinois Geol. Survey Rept. Inv. 135.*

[6] *Ibid.*, Fig. 6, logs 8–18.

FIG. 6.—Gray silty carbonaceous Waltersburg shale representative of core, depth 1,795–1,806 feet, Sun Oil Company's W. A. and N. Anderson Comm. No. 1, 23-O-19, Morganfield South field, Union County, Kentucky, showing carbon flakes and parallel-veined impression of *Cordaites* leaf fragment. ×3.4

FIG. 7.—Thin section of laminated shale and siltstone, depth 2,133 feet, Madison Coal Company drill hole No. 25, Sec. 12, T. 8 S., R. 3 E., Williamson County, Illinois, by plane polarized light. There is no visible porosity in this section of the coarsest rock in the entire Waltersburg section in this drill hole. ×66

FIG. 8.—Thin section field of Figure 7 between crossed nicols. ×66

FIG. 9.—Porous productive Waltersburg sandstone representative of 15-foot core, depth 1,792–1,807 feet, Sun Oil Company's W. A. Anderson No. 1, 23-O-19, Morganfield South field, Union County, Kentucky, 660 feet southwest of well from which shale core (Fig. 6) was taken. Magnification as in Figure 6. ×3.4

FIG. 10.—Thin section of porous productive Waltersburg sandstone, depth 2,167 feet, Carter Oil Company's Fuller No. 1, Sec. 11, T. 7 S., R. 8 E., Roland field, White County, Illinois, by plane polarized light. Porosity 19.5 per cent, permeability 1569 millidarcys by core analysis. Magnification as in Figures 7 and 8. ×66

FIG. 11.—Thin section field of Figure 10 between crossed nicols. Position of strained quartz and chert grains and of pores is noted in Figure 10. ×66

FIG. 6

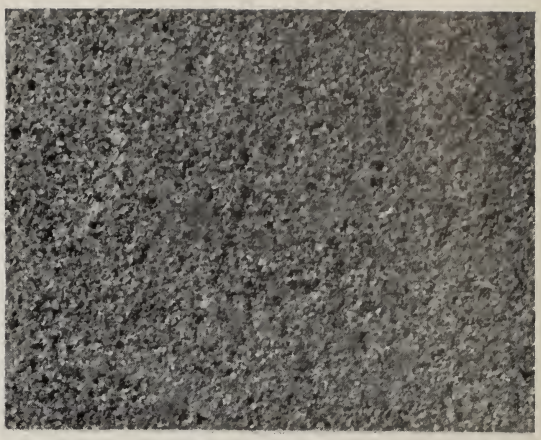


FIG. 9

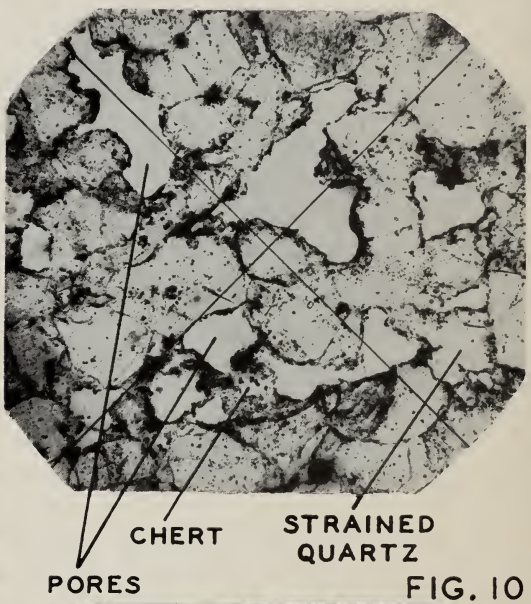


FIG. 10

FIG. 7

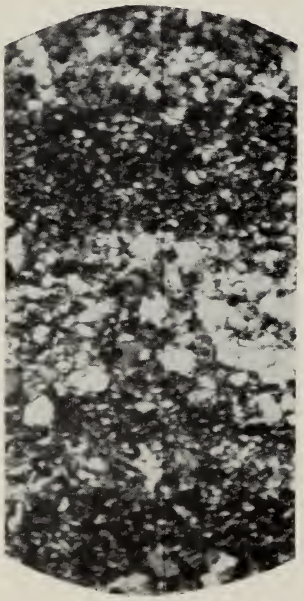


FIG. 8

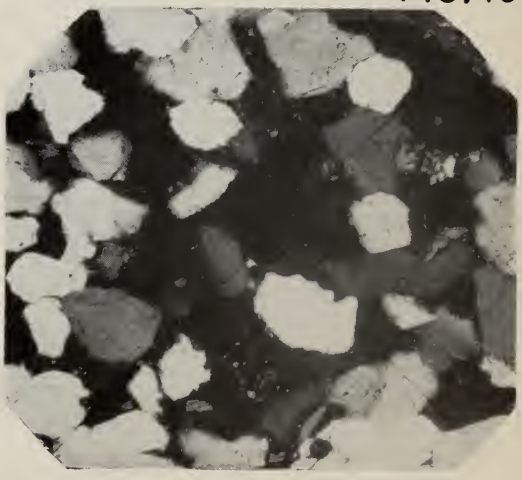


FIG. 11

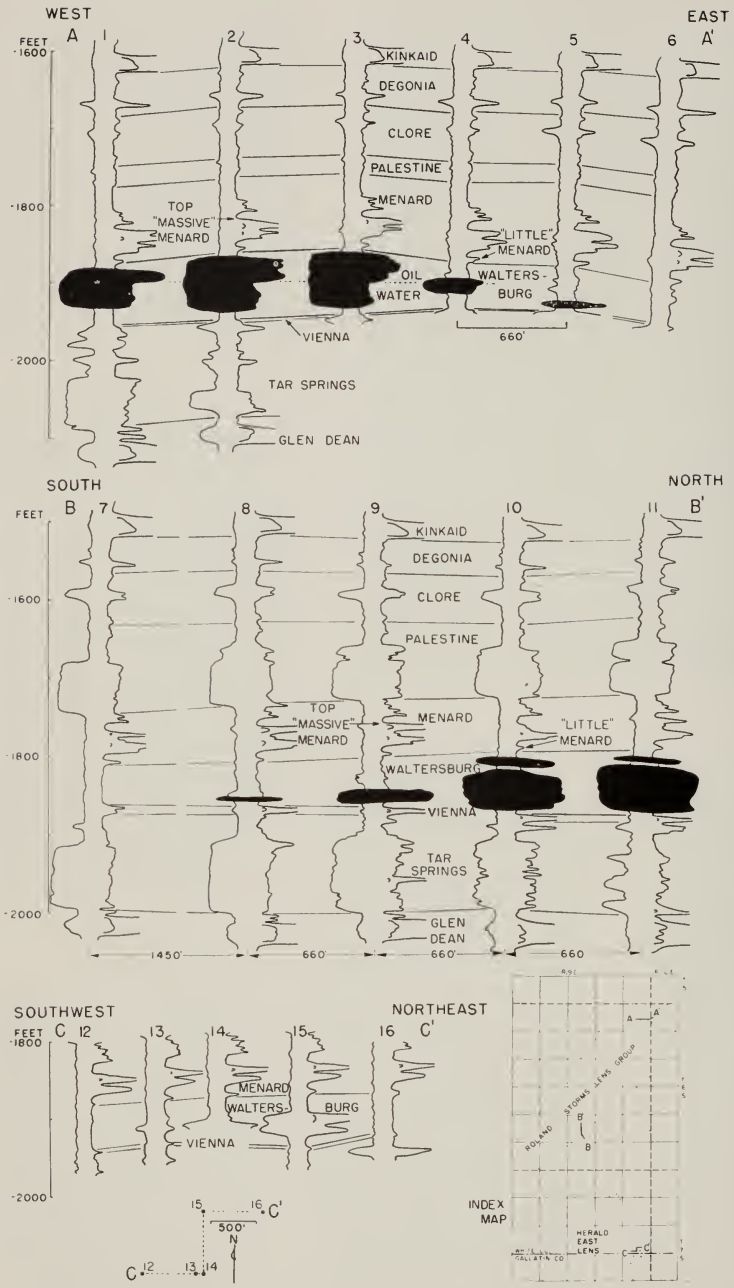


FIG. 12.—Electric-log cross sections of Waltersburg sandstone lenses, White County, Illinois: *AA'*, east-west in northern part of Storms pool; *BB'*, north-south in Herald field south of Storms pool; *CC'*, northeast-southwest in Herald East pool. Well reference number 1, Sinclair-Wyoming's John Stahl No. 1, NE. ¼, NE. ¼, SW. ¼; 2 and 3, Sinclair-Wyoming's E. Armstrong Nos. 2 and 4,

That some Waltersburg lenses occur in compound groups rather than as simple isolated bodies is illustrated in an east-west section through offset wells in the northern part of the Storms pool (Fig. 12, section *AA'*). Well No. 5 produces oil from a distinct lower lens isolated from the pay zone in the other wells and below the oil-water contact in those wells. This lens may be identical with the one in section *BB'* and the Storms complex lens may actually consist of a lower southeastern member which has a flat base and a parallel and overlapping northwestern upper member which has an irregular base. This hypothesis is suggested by cross sections at both the northeastern and southwestern ends of the Storms pool but can not be tested in the intervening area where almost all wells stop in the uppermost few feet of "pay."

SANDSTONE THICKNESS

The total thickness of effectively permeable sandstone in the Waltersburg of the lower Wabash area is shown in Figure 5. Most data are from electric logs. Only wells used as datum points are shown, although these include some wells which were bottomed in the sandstone and show minimum rather than complete thicknesses. Because very thin permeable beds are not clearly indicated by the potential curve when they are interbedded with low-resistivity rocks, it is possible that sandstones a few inches to as much as 3 feet thick may be present in the wells indicated as having no sandstone.

The Ribeyre Island lens, in the northeast part of the map, is about 60 feet thick at its center, more than 5 miles long, and $\frac{1}{2}$-$\frac{3}{4}$ mile wide at its widest. The main axis is northwest-southeast, but the eastern end is curved toward the south, and there is a suggestion that the body may turn through more than a right angle and continue into the lens in Sections 28 and 29, T. 5 S., R. 14 W. As nearly 2 miles separate wells in these lenses, no attempt was made to connect them on the map.

The Storms-Roland lens group is more than 16 miles long, 2 miles wide, and as much as 60 feet thick in several spots. It seems to be composed of a number of smaller bar-like lenses of the same general shape and orientation as the entire complex. Some of these smaller lenses overlap each other, but others are entirely separate.

The continuity of the single thick bar shown extending across the southeastern part of the map from the southeastern corner of T. 6 S., R. 14 W., to the western part of T. 8 S., R. 10 E., can not be proved. However, analogy with the

NW. $\frac{1}{4}$, NW. $\frac{1}{4}$, SE. $\frac{1}{4}$, and NE. $\frac{1}{4}$, NW. $\frac{1}{4}$, SE. $\frac{1}{4}$; 4, Sinclair-Wyoming's Jesse Stephens No. 3, NW. $\frac{1}{4}$, NE. $\frac{1}{4}$, SE $\frac{1}{4}$; 5, Sinclair-Wyoming's H. Aldridge No. 3, NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, SE. $\frac{1}{4}$, all in Sec. 1, T. 6 S., R. 9 E. Reference number 6, Sam Gilpin's Land No. 1, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 6, T. 6 S., R. 10 E. Reference numbers 7 and 8, Pure Oil Company's Jake Aud "A" Nos. 3 and 1, SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$, and SE. $\frac{1}{4}$, NE. $\frac{1}{4}$, SW. $\frac{1}{4}$; 9, Bates and Lichlyter's M. D. Aud No. 1, NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, SW. $\frac{1}{4}$; 10 and 11, Skelly's E. T. Aud Nos. 1 and 2, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, NW. $\frac{1}{4}$, and NE. $\frac{1}{4}$, SE. $\frac{1}{4}$, NW. $\frac{1}{4}$, all in Sec. 27, T. 6 S., R. 9 E. Reference numbers 12–15, W. Duncan's Bayley-Neville Comm. Nos. 4, 2, 1, and 3, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$, 50 feet west of center, SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$, center SE. $\frac{1}{4}$, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$, and NE. $\frac{1}{4}$, SE. $\frac{1}{4}$, SW. $\frac{1}{4}$; 16, Ohio Oil Company *et al.* Herman Grant No. 3A, NW. $\frac{1}{4}$, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$, all in Sec. 13, T. 7 S., R. 9 E.

Ribeyre Island lens suggests this solution despite the fact that the thick sand section in the dry hole in Sec. 16, T. 7 S., R. 14 W., is the only supporting link joining the lens at Inman East pool with the one at Mt. Vernon pool. The intervening areas with no data are rather large. It may be that this bar should be broken into two or three segments. It is also possible that in much of the sparsely drilled area bordering the bar on the southeast there may be 10–20 feet of sandstone. On the map it is indicated as being largely devoid of sand.

The area of thick sandstone in the southeast corner and along most of the eastern border of the map is the western edge of a belt about 20 miles wide in which the Waltersburg includes essentially continuous sandstone, with only a few local shale sections.

Comparison of Figures 2, 4, and 5 shows that the presence of permeable sandstone and the shape of the sandstone lenses are factors which, in addition to the structure, control commercial oil accumulations in the Waltersburg.

ORIGIN

The petrographic character of the lenses of "Island" Waltersburg sandstone and of the shale in which the lenses are completely imbedded implies that these rocks were derived from a sedimentary source area, removed by several cycles of erosion from the igneous and metamorphic terranes in which the individual quartz grains originated. The complete lack of feldspar as well as the presence of chert grains is indicative of a sedimentary source. There has not been sufficient work on diagnostic minerals to identify the source area. That the bulk of sediment must have entered the present Eastern Interior basin across the eastern half of the southern border of that basin is suggested by the size distribution of Waltersburg sediments, both sandy and shaly phases being finer-grained at the northern limit of preservation than at the southern, and the sandy phase being largely confined to the east-central part of the basin. The southern origin of the Waltersburg seems more likely when a comparison is made with other Chester clastic units, nearly all of which are thickest and coarsest along the southern boundary of the basin.

The very clean character of the "Island" sandstone bodies indicates a depositional environment which was unusually effective in sorting and in cleaning the oil-bearing facies. The shape of these elongate, flat-bottomed sandstone bodies, their composition, and the character of the underlying marine and overlying terrestrial, or at least near-shore, shales (evidenced by fairly well preserved leaves of land plants) indicate that they were deposited by waves and currents as beaches or near-shore bars.

This hypothesis of the origin of these bodies is substantiated even more strongly by their setting in a regional framework. Figure 13, which is based on the study of the logs of about 9,000 wells, shows the occurrence of sand in the Waltersburg in a larger area of Illinois. Detailed maps of the Waltersburg in most of the Indiana and Kentucky parts of the basin were not prepared, but in general there is

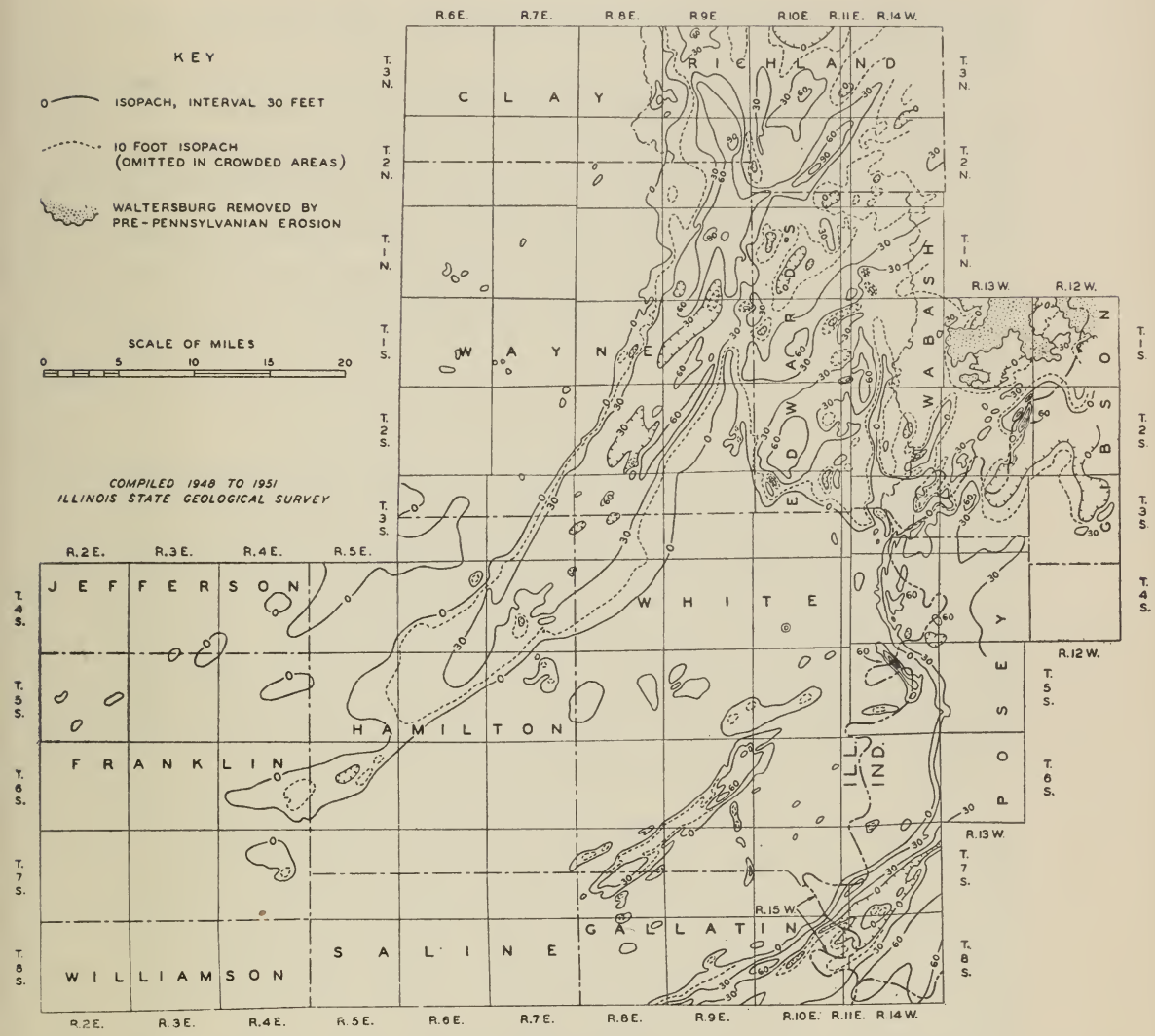


FIG. 13.—Thickness of permeable sand in Waltersburg formation of central basin. Simplified slightly from detail maps based on about 9,000 control points.

a belt 10–20 miles wide just east of the Wabash River, in which the Waltersburg is nearly a sheet sand, varying from 50 to 100 feet in thickness, though broken locally by beds of shale. Farther east there are other elongate sandstone bodies apparently somewhat similar to those shown in Figures 5 and 13. As indicated by Swann and Atherton,[7] the bodies fairly close to the sheet-sand area are likely to be thick with little shale, whereas those farthest east, approaching the Indiana

[7] D. H. Swann and Elwood Atherton, *op. cit.*, Fig. 6.

outcrop belt, are thinner, shalier, and in many places divided into upper and lower members.

Waltersburg deposits in the Eastern Interior basin were formed of sand and clay swept into the gradually emerging basin by streams from the south. A complex delta in western Kentucky and southwestern Indiana was built up east of the lower Wabash area. Wave action sorted the deposits and spread the clay and silt widely over the basin floor while the sand was carried by currents into beaches and bars east and west of the delta. In the course of time it is probable that most of the basin was built up to shore level and that land conditions extended out from the south to cover much of the basin area before re-advance of the sea allowed deposition of the marine "Little Menard" limestone over the entire area.

OIL ACCUMULATION

Oil production from Waltersburg sandstone has been confined to the eastern flank of the Eastern Interior basin. In Indiana and Kentucky there are pools in which the Waltersburg seems to be a sheet sandstone, producing only on top of structural highs and in a few places having a water drive. The accumulations in the southern part of Inman East, in Jeffries, which is the small field south of Mt. Vernon (Fig. 2), and in the northern part of the New Harmony area are the westernmost examples of this type of production. The most prolific pools, however, are those within the isolated lenses such as Ribeyre Island, Mink Island, Storms, and the two accumulations at Roland in the lower Wabash area, Rochester higher up the Wabash valley, and Morganfield South in Kentucky.

There is no sandstone in the Waltersburg formation in the far western parts of the basin, but in the central part of the basin north and west of the productive lower Wabash area there are sand bodies in Wayne, Hamilton, Richland, and northwestern Edwards counties (Fig. 13) which appear as favorable as those of the lower Wabash, but in which no oil has been found. Very striking is the close correspondence of the general area of Waltersburg sandstone oil production in the Eastern Interior basin with those of other middle and upper Chester sandstones—the Hardinsburg, Palestine, Clore, and Degonia, and, to a less degree, the Tar Springs and most of the Pennsylvanian sandstones.

Several hypotheses have been proposed to account for the lack of oil in the Waltersburg of Wayne, Hamilton, and Richland counties in contrast to the large amounts found in White, Gallatin, southern Edwards, and Wabash counties, and in near-by Indiana.

A suggestion that lithologic facies may define the productive region gains little support from the map of sandstone distribution, nor do there appear to be any subtle lithologic changes in either the sandstone or the surrounding shales which might account for any great difference in regional productivity. In both regions there are many areas with only shale, some isolated sand bodies, some relatively

continuous sand bodies, some thin sands, and some thick ones. Every lithologic type that occurs in one region occurs in the other. Although facies changes are predominant factors controlling the individual pools of Waltersburg oil within the productive region, the boundaries of that region cut across facies lines.

Nor do lithologic variations in either the overlying Menard or the underlying Vienna sediments appear to affect the productivity of the Waltersburg. Both formations thin, and the proportion of shale rises in each northward or northeastward, the changes being most marked in a direction trending nearly at right angles to the boundary of the productive area.

The most convincing evidence against regional facies control of Waltersburg production is indirect. Except for such readily explained minor deviations as those due to absence of Degonia, caused by pre-Pennsylvanian erosion, or shaling-out of Hardinsburg or Waltersburg over entire townships, the productive regions of middle or upper Chester sandstones, other than the Tar Springs, are very similar. Though the areas containing oil in all these formations are nearly identical, the depositional patterns of the several formations are quite dissimilar. The maximum development of sandstone in the Waltersburg is largely within the productive region; the Hardinsburg and Palestine sandstones are best developed along the boundary between the productive and non-productive regions; sandstone in the Clore formation is thickest and most nearly continuous in the non-productive area a short distance west of the boundary; the Degonia is thick at the very western edge of the basin, with a second maximum near the eastern edge, and is thin over most of the productive region. Since these formations contain oil only in the same general region despite their varied geographies, it is improbable that the cause of the common productive region can be found in the paleofacies study of any one of the formations.

Some geologists have expressed the belief that because of the continuity of the main bar-like Waltersburg body sweeping across Wayne and Hamilton counties any oil was flushed out of it or escaped updip northward to the pre-Pennsylvanian outcrop. However, other sheet sands on the east contain oil, and there are many minor irregularities in this bar which should have trapped at least some oil in the 100-mile stretch from the southwestern tip of the body to the pre-Pennsylvanian cut-off at its northeastern end a considerable distance north of the edge of Figure 13. The flushing of the western bar would not explain the remarkable coincidence of the productive regions of the other middle and upper Chester sands with the Waltersburg area.

The post-depositional histories of the productive and non-productive regions are similar with one important exception. The post-Waltersburg Chester deposits, pre-Pennsylvanian erosion, Pennsylvanian deposits, present depth of burial, and the size and complexity of the folds in the two regions are comparable, but there is no known faulting in most of the parts of the basin without Waltersburg production. The correspondence of the Waltersburg pools and of most upper Chester productive areas with post-Pennsylvanian normal faulted regions is

striking, and much of the significant Pennsylvanian production of the Eastern Interior basin is related to the same faults.

The geographic distribution of quantitatively important post-Devonian oil pools in the basin can be summarized by three statements: first, the Ste. Genevieve formation, or the formation replacing it at the top of the Lower Mississippian where erosion has cut deeply, and the lower Chester formations up to and including the Cypress are in a broad sense productive throughout the basin wherever local structure and facies are favorable; second, Lower Pennsylvanian formations are productive where the pre-Pennsylvanian unconformity cuts the Ste. Genevieve-Cypress interval; third, middle Chester, upper Chester, and the entire Pennsylvanian section, as well as the Ste. Genevieve and lower Chester formations, are potentially productive in the areas with known faults. Despite exceptions to these three generalizations, they lend strong support to the conclusion that the great bulk of the oil in the basin originated within about 400 feet of rock at the top of the Lower Mississippian and the bottom of the Chester, and migrated either across the pre-Pennsylvanian unconformity or up fault lines to higher reservoirs.

Nearly all Waltersburg oil has been discovered within 4 or 5 miles of known faults, and in most places a clear path can be traced from the fault to the pool (Figs. 2, 4, 5). In other pools, such as Herald East, no connection can be proved, but it is possible that closer drilling would show a continuous sand body extending across the Herald fault line to Storms (Fig. 5). In still other cases, as at Rochester pool on the Wabash River in T. 2 S., R. 13 W., there has been so much drilling between the pool and the nearest fault, here a little more than a mile southwest, that it is unlikely that an undiscovered sand connection with the fault line exists. Fleener, a small pool in an isolated Waltersburg lens in the southeastern part of T. 3 S., R. 12 W., Gibson County, Indiana, is too far from a known fault for explanation by a hypothesis of migration of oil along fault planes.

To recapitulate, the chief characteristic differentiating the parts of the basin in which the Waltersburg produces from those in which it is barren appears to be post-Pennsylvanian faulting rather than the Waltersburg facies relationships. However, there are some oil deposits in the faulted productive region which can not be attributed to faults. Within the productive region the localization of the separate Waltersburg pools is dependent on facies relationships, and a number of the pools are trapped by conditions due to facies boundaries rather than structure.

EXPLORATION

The older Waltersburg pools of the lower Wabash area and near-by regions were discovered between 1938 and 1944 on a strictly structural basis. Wells drilled on highs known through coring, seismographing, or subsurface correlation chanced to find Waltersburg sandstone bodies. Some Waltersburg pools were found by development wells drilled through the Waltersburg to known lower

producing sands. The main Roland production, Storms, Inman East, Ribeyre Island, the more northerly pools in the New Harmony field, Uniontown, Kentucky, and Heusler, Indiana, were thus discovered.

In the last 5 or 6 years the information available has been sufficient to foster the search for Waltersburg pools on a facies basis. There were three discoveries during 1947 and 1948 of Waltersburg reservoirs with 1 to 10 million barrels of reserve. One of these, the Rochester pool in the northeastern part of T. 2 S., R. 13 W., Wabash County, Illinois, and Gibson County, Indiana, was found as a result of drilling on a structural terrace which had become evident through subsurface study. Rochester should thus be credited along with the earlier Waltersburg pools to drilling guided by a purely structural approach.

On the other hand the discovery of the Mink Island or New Harmony South (Indiana) Waltersburg pool resulted from a deliberate program of tracing the known Ribeyre Island lens across a fault line into the upthrown block bounding the New Harmony graben on the east. There were two or three failures caused by the unexpected sharp bend in this lens before the Mink Island deposit was finally discovered.

The southwesternmost extension of Roland pool was an outstanding success of facies-influenced exploration (Figs. 4, 5). A prediction that the Storms-Roland Waltersburg bar would extend up onto the flank of the Omaha dome was proved correct, and resulted in finding a pool in a situation which on a purely structural basis appeared hopeless. The structure of the northern flank of the dome had been known for years and its configuration was modified very little by the Waltersburg pool (Fig. 4). Likewise, information on the Waltersburg sandstone bar within the White County area was available (Fig. 5). In the sequence of drilling leading to discovery the first test was too far south to encounter the lens, the second was too far northwest, but the third was in the upper, southern edge of the lens, and was completed as a small producer.

Delineation of facies and the successful prediction of resultant stratigraphic traps will be more and more important in the Eastern Interior basin in the future, not only in the Waltersburg formation but also in the other Chester sandstones, and probably in the lower limestones. The structural traps of this province have largely been exploited and much of the future production of the basin must come from sand traps and limestone porosity traps on monoclines and terraces.

Future Waltersburg discoveries of importance will be made largely in the general region from which present production comes. Within this region the largest and most likely untested areas lie in the fault blocks low on the downthrown sides of the faults. Any lens which can be traced through a fault line into a downthrown block and disappears before the area of closely spaced tests is reached at the crest of the next anticlinal belt or fault should be considered a potential oil trap in the downthrown block.